INTERNATIONAL JOURNAL OF PLANT, ANIMAL AND ENVIRONMENTAL SCIENCES
IJPAES
Volume-4, Issue-3, July-Sept-2014
ISSN 2231-4490

Coden : IJPAES www.ijpaes.com
Received: 4th April-2014 *Revised: 24th May-2014* *Accepted: 25th May-2014*
Research article

EFFECT OF TEMPERATURE ON DRYING KINETICS, ANTIOXIDANT CAPACITY AND VITAMIN C CONTENT OF PAPAYA (*CARICA PAPAYA* LINN.)

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ABSTRACT: Papaya is a tropical fruit rich in bioactive compounds such as vitamins and antioxidant compositions. In the present study, papaya was dried as single layers with thickness of 3 mm in the ranges of 50-70^{o}C inlet air temperature and 1±0.2 m/s air velocity in a laboratory scale cabinet dryer. The effect of the air-drying temperature on drying kinetics, antioxidant capacity and vitamin C content of the papaya was investigated. Papaya was dried to equilibrium moisture content within a time range of 210-390 min under these drying conditions. Moisture transfer from papaya slices was described by applying the Fick's diffusion model, and the effective diffusivity changes between 1.27×10^{-9} and 3.78×10^{-9}.
Effective diffusivity increased with increasing temperature. The radical scavenging activity showed higher antioxidant activity by increasing temperature. Vitamin C content also decreased as air-drying temperatures increased.
Key words: Papaya, Air-drying, Drying Kinetics, Antioxidant capacity, Vitamin C

INTRODUCTION

Consumption of some fruits and vegetables significantly influence the health of the consumers because of their high nutritional value. Tropical fruit are rich in bioactive compounds such as vitamins and antioxidant compositions. Papaya is a fruit widely grown in tropical and sub-tropical regions. Brazil with a 40% annual production rate is the major producers of this fruit [7, 15]. Papaya is a low-calorie fruit rich in vitamins and minerals such as vitamins A and C, Riboflavin, folate, and calcium. This fruit's high fibre and low-calorie content makes it an invaluable nutritional source for the obese. In comparison to fruits like apple and guava papaya has a higher carotene content which plays a crucial role in the control of free radicals. In fact this fruit's high nutritional value and excellent sensory properties can be considered the main reason for its suitability within the human diet [15]. The city of Sarbaz in the Province of Sistan and Balouchestan is the only region in Iran that enjoys the appropriate cultivation environment. Because of the high price of this valuable fruit in the consumer market and its specific preservation conditions which makes this fruit highly sensitive to putrescence, the design of appropriate processes to extend the shelf-life of this fruit and maintain its functional and nutritional properties seems extremely necessary. One approach to achieve the above mentioned aim is the design and improvement of the drying procedures. Drying is a preservation method with applications in many industrial and agricultural products [22]. This unit operation is defined as the elimination of moisture by the simultaneous transfer of mass and heat which reduces the water activity and consequently increases the shelf-life of the product [1]. Hot air drying is the most common procedure among all drying methods .This procedure not only reduces the weight and volume of the fruit and depreciates storage and transport costs [21] but also facilitates the use of the products in non- harvest seasons [14].
An appropriate preservation method not only must reduce water activity to a level that ceases bacterial and chemically destructive activities, but also well-preserve mechanical, textural, nutritional, physical properties , etc in the product [6]. The knowledge of the kinetics during the drying process provides vital information for design, improvement, and the control of the said process and leads to the production of a high quality and nutritionally enriched product. The aim of this research is to investigate the effect of drying temperature on drying kinetics, antioxidant properties, and vitamin C content of Papaya.

MATERIALS AND METHODS

Raw material and drying conditions

Fresh papaya was collected from the orchards within the city of Sarbaz (Sistan and Balouchestan Province, Iran). The samples were peeled and the core seeds removed and then cut into 3 mm thick slices using a sharp knife. The slices were weighed and were placed evenly as a thin layer on a tray of a cabinet dryer with forced convection (Model JE10 TECH, F-02G, South Korea). The drying process was carried out at three air temperatures; 55, 65 and 75˚C which was controlled in automatic form, using a PID controller. The air velocity was kept constant at 1± 0.2 m/s which measured by a digital hot wire anemometer (Lutron, Model AM4204, Taiwan). Drying continued until the samples reached a constant weight (equilibrium condition). The initial moisture was measured according to the AOAC 934.06 Standard [3].

Calculation of effective moisture diffusivity and drying rare

Moisture ratio of the samples during drying process was calculated by the following equation:

$$MR = \frac{M - M_e}{M_o - M_e} \qquad \textbf{(1)}$$

Where MR is Moisture ratio, M is Moisture content at specific time (kg water per kg dry solids), M_0 is Initial Moisture content (kg water per kg dry solids), M_e is Equilibrium Moisture content (kg water per kg dry solids). Equilibrium moisture is measured once the weight reduction has ceased in each treatment. The second Fick's diffusion equation was applied to investigate the transfer of mass in papaya samples and the effective water diffusivity:

$$MR = \frac{8}{\pi^2} e^{\left(-\pi^2 \frac{D_{eff} t}{L^2}\right)} \qquad \textbf{(2)}$$

Where D_{eff} is Effective diffusivity (m^2/s), L is half thickness of slab (m) and t is dehydration time in minutes. This equation is used widely to describe the drying characteristics of biological products in falling rate period.

The drying rate of papaya sample was calculated by the following equation:

$$D.R = \frac{M_{(t+\Delta t)} - M_t}{\Delta t} \qquad \textbf{(3)}$$

Where $M_{(t+\Delta t)}$ and M_t are moisture content at time t+Δt and t (kg water per kg dry solids) respectively and Δt is time interval (10min) [1, 19].

Evaluation of Antioxidant Activity

Antioxidant activity of the dried sample was measured on the basis of scavenging activities of the stable 2,2–diphenyl-1-picrylhydrazyl ($DPPH^0$) radical [2, 23]. The percentage of antioxidant activity (AA %) was calculated by the following equation:

$$AA\% = \left(A_{blank} - A_{sample} / A_{blank}\right) \times 100$$

Where:

A_{blank}= the absorbance of control reaction (Methanol- water with DPPH)

A_{Sample} = the absorbance of tested sample.

Evaluation of Vitamin C content

Vitamin C content was evaluated by the 2,6-dichlorophenol –indophenol titrametric method according to AOAC method NO.976,21 [4]. Evaluation was replicated three times and the vitamin C content was measured in mg Vit. C per 100g dry matter.

Statistical Analysis

The results were analysed by an analysis of variance (ANOVA). Differences between the media were analysed using the least significant difference (LSD) test with a significance level of a = 0.05 and a confidence interval of 95% ($p<0.05$).

RESULTS AND DISCUSSION

Drying behaviour papaya slices

The initial moisture content for samples in this research measured at 760.05% (dry basis). The equilibrium moisture content varied from 3.1 to 3.8 % d.b. The time required to reach equilibrium moisture content was linearly reduced by the increase in the drying temperature (R^2=98.6) such that the dehydration times at 55°C, 65°C , and 75°C were measured at 390, 300, and 210 min respectively.

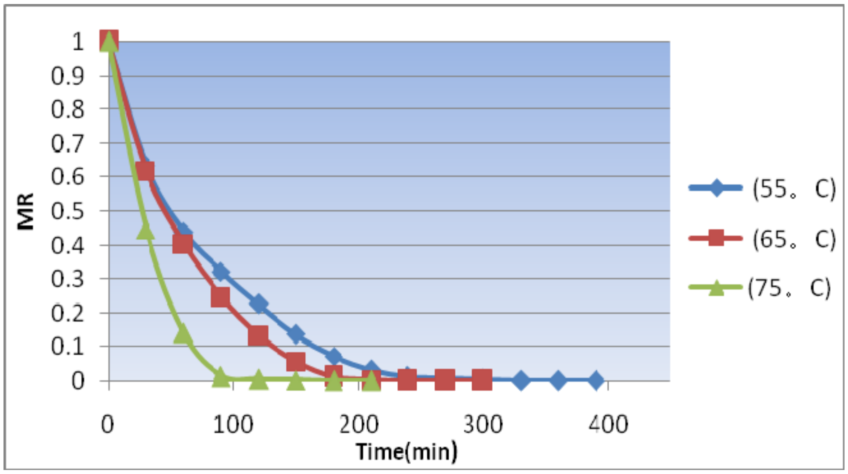

Figure 1. Drying curves corresponding to the dehydration of papaya slices at various temperatures

The drying rate was calculated from equation 3 and plotted against moisture content (figure 2). The maximum drying rate observed at 75°C by 0.031 (kg water per kg d.m min). The mean drying rate for 65°, and 55°C was calculated at 0.25 and 0.19 (kg water per Kg d.m min) respectively. In all three samples in this research, a falling rate period was observed. Similar results were observed using kiwifruit, aloe vera and vegetables such as potato, carrot, pepper, garlic, and mushroom [13, 14, 19].

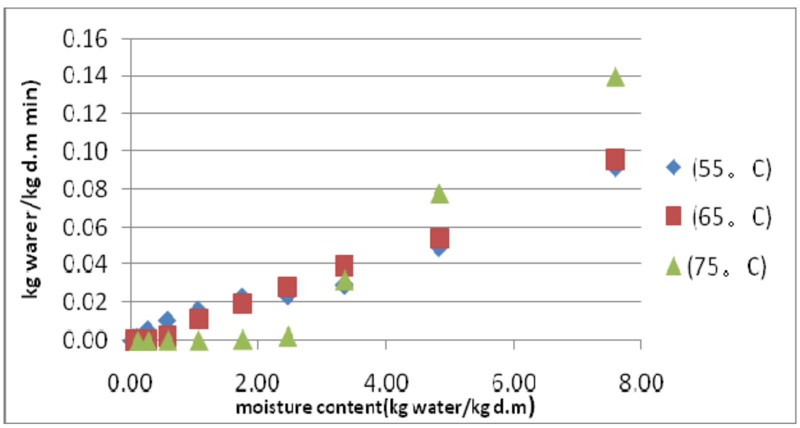

Figure 2. Drying rate changes of papaya slices during drying at different drying temperatures

Calculation of effective moisture diffusivity

The effective moisture diffusivity for three temperatures was determined through calculating the slope of the line formed by plotting experimental drying data in the terms of Ln (MR) versus drying time [17]. The values of the effective moisture diffusivity as given in table 1 varied between $1.72X10^{-9}$ and $3.78X10^{-9}$. These values are within the reported range for the drying of agricultural produce such as pepper [4], rhubarb [17] and aloevera [13]. The increase in the effective moisture diffusivity and the resultant reduction in drying time due to the rise in temperature can be related to the rise in vapour pressure difference between the surface and the centre of the product resulting in the subsequent rise in transfer of moisture out of the food [17].

Table 1. Water diffusion coefficient of of papaya slices during drying at different drying temperatures

Temperature (^{o}C)	effective moisture diffusivity (10^{-9} m^2s^{-1})	r^2
55 ^{o}c	1.72	0.9838
65^{o}c	2.71	0.9868
75^{o}c	3.78	0.9874

Vitamin C

The vitamin C content in the fresh and dried papaya samples are given in figure 3. The vitamin C content in fresh fruit was measured at 57 mg. The vitamin C content in papaya was reported 74mg and 151mg, respectively [8, 10]. The reason for these discrepancies can be explained by factors such as the extent of ripeness and the growing conditions of the fruit. As can be seen the drying temperature affected the decomposition of vitamin C so that the least amount of vitamin C was measured at 75°C. This can be related to the irreversible oxidization of vitamin C during drying [18]. The reduction in thermo sensitive vitamin C can also be attributed to the length of time required for dehydration at 55°C (390 min) [13]. From a functional point of view, vitamin C in combination with other antioxidants, including vitamin E, b-carotene, and phenolic compounds, provides a synergistic antihypertensive effect [10]. As papaya is enriched with some of these compounds [7, 15] access to drying conditions that retains most of the vitamin C content is of paramount importance.

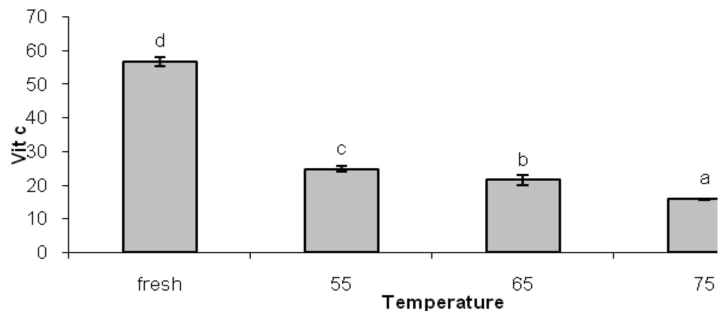

Figure 3. Ascorbic acid content in papaya air-dried at various temperatures

Antioxidant Activity

The highest antioxidant activity (59%) was observed in the t samples dried at 75°C. The samples dried at 65°C indicated a 57.3% level of antioxidant activity which is lower than those dried at 75°C even though the difference is statistically insignificant. The least level of antioxidant activity (39.3%) was observed 55°C. Some researchers found that dehydration at higher temperatures leads to a rise in antioxidant activity and increases phenolic compounds [22]. It has been reported that the production and accumulation of melanoid compounds resultant from the Maillard reaction which having a varying degree of antioxidant activity can be responsible for the increase in antioxidant activity at higher temperatures [13, 16]. The falling trend at lower temperatures (55°C) can be attributed to the long drying times resulting in the decomposition of antioxidant compounds [9].

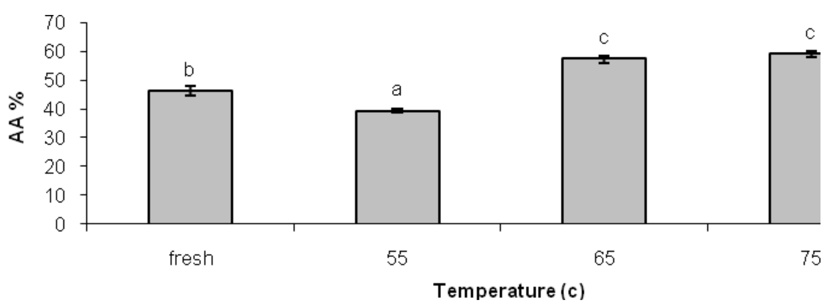

Figure 4. Antioxidant activity (%) in fresh and dried papaya Samples

CONCLUSION

This research investigated the effect of air-drying temperature on drying time and rate and on bioactive compounds of the papaya. The increase in temperature resulted in the reduction in drying time and also increased the rate of drying. The effective moisture diffusivity varied between 1.72×10^{-9} and 3.78×10^{-9}. The stability of nutritional compounds (Vitamin C) and the antioxidant capacity of the papaya were highly dependent upon temperature. The more the temperature increased the less the bioactive compounds such as vitamin C became, while at the same time a different trend was observed in antioxidant properties where the highest level of antioxidant activity was measured at 75°C. However, the vitamin C content and the antioxidant capacity were reduced in the dried samples when compared with the fresh papaya. The physiochemical changes in the samples during dehydration can significantly affect the physiological activities associated with this plant. The results of this research are in general essential for the improvement of industrial dehydration of the papaya in order to obtain dried papaya that contains high bioactive compounds.

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